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THE USE OF DOUBLE TRANSLOCATIONS TO CONTROL POPULATIONS OF THE --ETC(U)
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A pilot experiment involving the integration of routine insecticide treatments with releases of "sterile" males (double translocation heterozygotes) for control of the German cockroach was conducted on two ships at Norfolk Naval Base. The sterility mechanism, "embryonic trapping", is an ancillary effect of the high lethality associated with double translocations. Lethality reduces the number of living embryos so that their combined strength is insufficient to force open the egg case at the time of hatch. Double males causing complete sterility were developed and tested in the laboratory during the first 2 yrs. of

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this Contract. During the past year, the experiment on one ship, an ocean going tug, was completed.

Under Objective 1 of the 1979-80 Contract, crossing systems were established for the production of sterile males. Two systems perpetuated the parental translocation stocks; the third was intercrosses from which the progeny included double males (phenotypically wild-type). A weekly regime of crossing and selection led to production of 150-200 sterile males/wk. Objective 2 involved cooperative arrangements with Navy personnel, especially Drs. McDonald and Egan, through which experimental ships were found, populations reduced by regular treatment procedures, and 3 releases made at as close to monthly intervals as possible (4/19, 5/15, and 6/26). The initial and residual populations were estimated from timed collections made in the course of two treatments (Obj. 3). Releases were conducted at each of 6 sites of initial infestation on the main deck, plus a small release in the Chief's mess (5-7 males). The number released/site ranged from 15-19 at release #1 to 25-29 at release #3.

Comparisons of new vs initial infestations and records of insects trapped at release sites (wk prior to 8/5 & wk prior to 8/17) and of those collected at final cleanouts (8/17 & 8/29) were used to analyze the results (Obj. 4). Known biological properties of the species aided in estimating times of hatch and origins of nymphal age groups and of egg case-bearing females (Obj. 5). The latter were grouped as 1st & 2nd, 3rd, and 4th egg cases according to nos. of compartments (embryos)/egg case.

At termination of the experiment, there were more cockroaches and more infestation sites than present initially (new sites largely in mess deck). We attribute this to a dearth of information on wild-type behavior and population dynamics and under-estimation of residual groups, rather than to a defect in the genetic mechanism. Sterile males joined groups at or close to release sites. Comparisons of numbers released to numbers of sterile matings and of the frequency of sterile matings to estimates of sterile male frequency indicated the males competed well against wild type. In the galley, an avg. of 76% sterility after release #1 (70^{σ}) was insufficient to suppress growth, although releases did result in little or no increase in the rate at which new females matured within the population(s). In the mess deck, survivors of matings after release #1 collected at or near the release site (bench seat) showed a 91% sterility. This was not the case in the mess deck as a whole, where infestations became heavier than those of the galley, even though the galley had both lower sterility and larger residual groups. Several lines of evidence indicate this difference was due to insecticide-induced dispersal of nymphs from the bench site prior to release #1, followed by uncontrolled wild-type growth at newly infested mess deck harborages. Adult females tended to stay at or close to their particular harborage.

From this experiment, we conclude that (1) sterile males join and compete well within natural populations, (2) the sterile male technique remains a viable option but needs further testing, and (3) these or other genetic markers can be used to gain information on wild-type population growth and behavior.

OFFICE OF NAVAL RESEARCH

Contract #N00014-77C-0246

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ANNUAL REPORT NO. 3

The Use of Double Translocations to Control Populations of the German Cockroach

by

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March 1980

This Annual Report summarizes research conducted during the 3rd year of the Contract entitled "The Use of Double Translocations to Control Populations of the German Cockroach" (3/1/79-2/29/80). The overall goal was to conduct a first experiment in the use of a genetic mechanism as part of a cockroach control program. The first two years of the Contract saw the completion of the laboratory research and the establishment of cooperative arrangements necessary to initiating the "field" experiment.

The experiment was carried out aboard two Navy vessels at the Norfolk Naval Base. Due to circumstances beyond our control, we have results from only one of the two ships (the other has not returned to Norfolk). The cooperation of Navy entomologists stationed at Navy Environmental and Preventive Medicine Unit #2, namely LCDR John McDonald and Lt. Peter Egan, and that of skippers and other personnel aboard the experimental ships, made the experiment possible.

The accomplishments of the past year are reported below according to the objectives stated in the Contract for 1979-80.

Objective 1 - To produce sterile males, i.e., T(8;9),T(4;5;10) double translocation heterozygotes for release.

Crosses requisite to production of double (sterile) males were detailed in earlier reports. In brief, three crossing systems were maintained: two for the parental translocation stocks, T(8;9) and T(4;8;10), and one for production of sterile males ($T(8;9)^{\sigma}$ X $T(4;5;10)^{\varphi}$). Each week, newly hatched nymphs of the three systems were separated from their parental females by a seiving technique. At 4 wks of age (4th instar), the nymphs were phenotyped and sexed. In the parental systems, about half were used for stock maintenance; the others, for new intercrosses. Among the intercross progeny, only phenotypically normal males were saved. These were the sterile males (double translocation heterozygotes). Siblings showing the phenotype of one or the other genetic marker used in translocation identification were discarded.

It was necessary to set up intercrosses for production of sterile males several months ahead of the 1st release (2-3 wks for selections to mature + 1 mo. to hatch of first egg case + 1½ mo. for sterile males to mature). At this time, we had no information which would enable us to even roughly estimate the numbers needed for monthly releases. Therefore, we simply expanded the three systems as rapidly as possible until we reached the maximum we were capable of producing with available personnel and space. First hatch of double males began in January 1979. Selections, initiated in March, showed an increase from 23 sterile males in the first week to 100 three weeks later. The crossing systems were no longer expanded once we had reached a production of 2-300 sterile males/week (May 1979).

Objective 2 - Cooperation with Navy entomologists in making arrangements for the field trial.

Arrangements for two experimental ships, i.e., an ocean going tug (USS Papago) and a LST (USS Boulder), were made by LCDR McDonald and our liaison officer, Lt. Egan. Preliminary reduction and sampling of the

shipboard populations was made possible through their cooperation. Subsequently, we kept in close contact with Drs. McDonald and Egan. They arranged for carrying out the releases at times as close to the experimental design as possible in view of ships' schedules. Lt. Egan periodically checked with ships' personnel in an attempt to roughly monitor experimental results as to whether there was a comeback in population numbers. This appeared to be the case on the Papago at about 6 wks after the last release. We supplied traps to Dr. Egan. We and Dr. McDonald brought them to our laboratory, following trapping for 1 wk at selected sites on the Papago. Following consultation, it was decided to terminate the experiment. Some additional trapping of live cockroaches (see Obj. 4) was carried out prior to final cleanout-collection.

Objective 3 - Releases of sterile males.

The accomplishment of this objective is outlined below according to pre-release procedures and those of the actual releases.

1) Pre-release

a. Treatment: Pyrethrins spray was used to locate infestation sites and 1% baygon in oil for kill. Four treatments with accompanying collections were made on the Boulder (3/21, 4/2, 4/9, & 4/26), and two on the Papago (3/21 and 4/2).

b. Collections: Collection was made with a vacuum-type apparatus and the insects were preserved in 70% alcohol. Every effort was made to locate all harborage sites and to make sampling as uniform as possible (timed collections). The collections were not separated as to site although notes were taken on heavy vs lighter infestations. Counts from successive collections were as follows:

Boulder: 383 (299 adults, 84 nymphs); 222 (154 ad, 68 ny); 527 (431 ad, 96 ny), 77 (66 ad, 11 ny)

Papago: 128 (67 ad, 61 ny); 40 (23 ad, 17 ny)

c. Analysis: Collections were subsequently recorded as to instar, sex, and nos. of egg cases. A population estimate based on the removal method of Seber & LeCren and Seber & Whale was used to analyze these data. Mr. Keil has a nearly completed manuscript reporting these results of which a copy will be forwarded to ONR as soon as possible. His analyses indicated a population reduction of 90% on the Papago (but see Obj. 4). On the Boulder reduction from 4 treatments was estimated at 88%, leaving an estimated residual group of 164 cockroaches.

Near equality between adult and nymphal numbers on the Papago suggest there was an actively growing population(s). More stabilized populations, as apparently occurred on the Boulder and in certain apartments studied in Raleigh, N. C. (Sherron, Wright,

and Ross, unpubl.), showed higher proportions of adults. Adult males were more susceptible to treatment than other age classes/sexes. Overall, lowest catchability was among adult females and small nymphs (Keil, unpubl.), although later data indicated this varied as to site and general area (see p.12).

2) Releases

Sterile males were released at sites pre-selected as those harboring cockroaches at the initiation of the experiment. We report here only on the Papago experiment, as this is the only one from which we have results at the present time. There were 7 sites of initial infestation (Figure 1, 1-6, plus the Chief's Mess). The heaviest infestations were in the galley. There were a few cockroaches in the scullery and on the Chief's Mess, and a moderately heavy group in the bench seat on the mess deck. No other harborage was found on the mess deck. Males released at these sites ranged in age from 5-6 wk-old nymphs to 1 & 2 wk-old adults, although the adults made up at least 75% of each release. Males for release at each site were pre-packaged in small ice-cream cartons. Numbers for the 6 sites on the main deck ranged from 19-20/carton for the 1st release to 29-30 for the 3rd release. Due to the small size of the original infestation, no more than 6-7 males were released at any one time in the Chief's Mess. Release dates and total numbers were as follows: 120 ♂ on 4/19; 145 ♂ on 5/15; and 180 ♂ on 6/28. The targets were newly maturing females within the shipboard populations. These were expected to come from three sources: residual nymphal groups that survived treatment; progeny of wild-type matings that took place prior to release (adult female survivors of pre-release treatment); and, in case of rel. #3 only, progeny of any non-sterile matings that occurred in the period between release #1 and 2 (Table 1).

Table 1. Dates of release and target groups.

Date of release	Target group (groups with newly-maturing females)
April 19 (rel. #1)	Medium to large nymph of residual groups (nymphs that escaped/survived treatment (expected mature ca. April 19-May 3).
	Small to medium nymphs of residual groups (expected mature ca. May 4-14); possibly some pre-release hatch from females carrying mature oothecae at time of treatment.
May 15 (rel. #2)	F_1 progeny of 1st post-treatment egg cases of adult females of residual groups (hatch ca. April 2-May 15).
June 26 (rel. #3)	F_1 progeny of 2nd post-treatment egg cases of residual adult females and, if any occurred, those of 3rd egg cases could mature by late July-early Aug.
	Progeny of any non-sterile matings that occurred in period between rel. #1 & #2.

Objective 4 - Collections for determining the effects of the releases.

Two sets of traps were used to collect live cockroaches prior to insecticide treatments and collection that terminated the experiment. Four traps were left out for 1 wk prior to pickup on August 5 (1 in the corner of the galley; 1 on the galley shelf, 1 in the gear locker, and 1 in the bench seat -- Figure 1, sites 9, 7, 13, and 11, respectively); four more were placed out for pickup on August 17 (Figure 1, sites 9, 8, 13, and 11, of which that in the galley disappeared). Cleanout-collection on August 17 and again on August 29 differed from procedures used initially in that the effort was directed towards as complete a kill and collection as possible. Earlier collections were timed; the termination collections were continued until no more cockroaches could be found.

Objective 5A - Evaluation of the results.

Several lines of evidence were used to indicate the performance of the sterile males under shipboard conditions and to gain information concerning growth and movement of groups inhabiting different harborages and/or areas. In the latter respect, a fortuitous situation occurred in that population development within the galley turned out to be very different than on the mess deck. A comparison between the two accounted for sterility effects and aspects of wild-type population growth which we would not otherwise have been able to interpret. This study apparently provides the first analysis of wild-type population development within shipboard populations, if not of natural populations of this species in general.

The data basic to our analyses are as follows:

a. Location of new vs initial infestation sites; field notes on comparative densities.

b. Categorization of oothecae of field-mated females in respect to size (nos. embryos/ootheca) and mating type (sterile vs wild-type).

c. Relative proportions and numbers within nymphal age classes, grouped as to "large" (5th-6th instar), "medium" (3rd-4th instar) and "small" (1st-2nd instar).

d. Frequency of sterile males among those collected from two of the traps (mated to laboratory wild-type females).

Basic biological data used in the interpretation of these data were: an avg. nymphal development of 6-8 wks; 1 mo between maturation and mating to hatch of 1st egg case; 1 mo between hatch of successive egg cases; and most hatch within the population was from 1st, 2nd, and, to a lesser extent, 3rd egg cases. In addition, size groups and comparison of these to laboratory data were used to classify egg cases as to approximate age, i.e., 1st & 2nd egg cases (indistinguishable; females 1-2 mo-old); 3rd egg cases (3 mo-old females) and 4th egg cases (4 mo-old females), as shown in Figure 2.

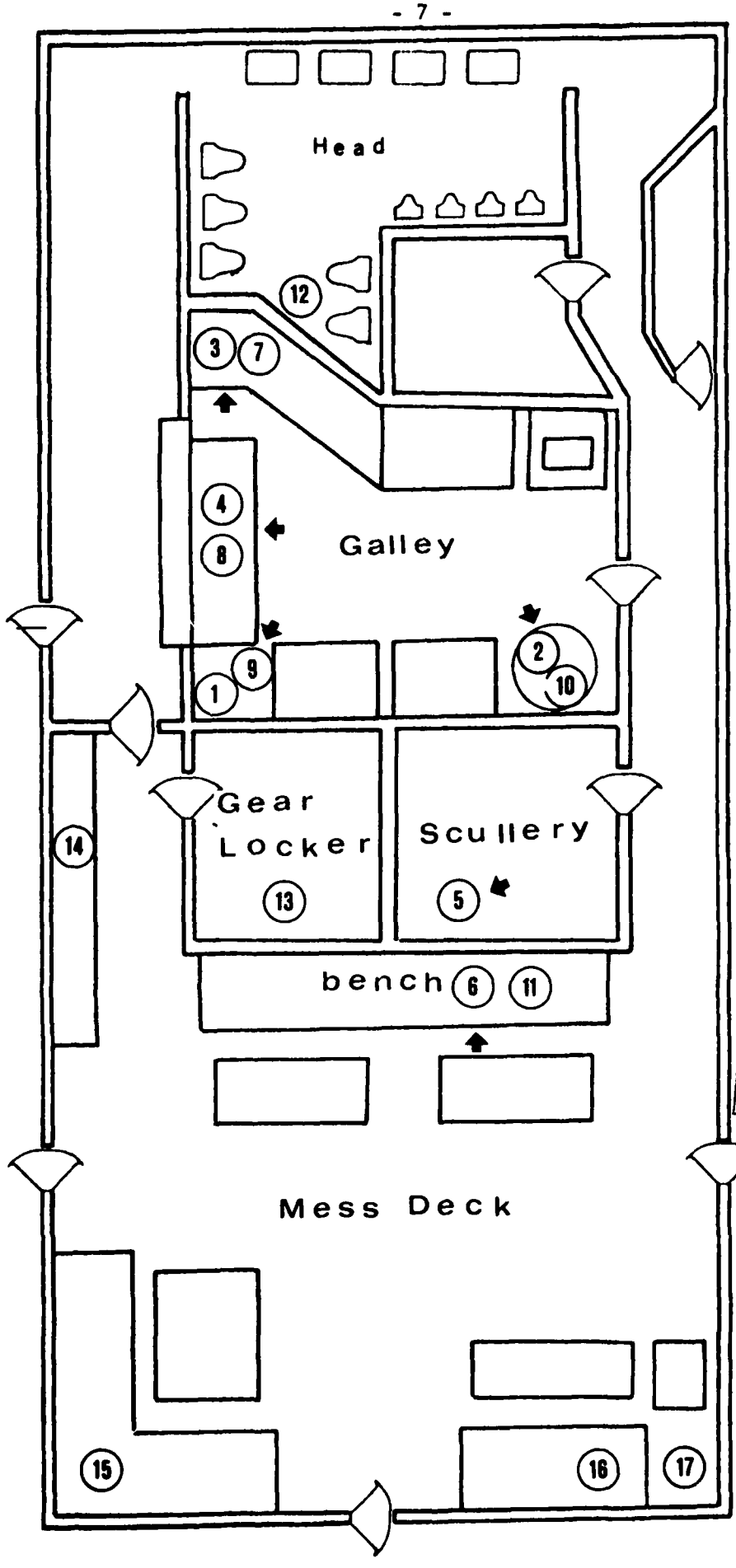


Figure 1 - Map of main deck.

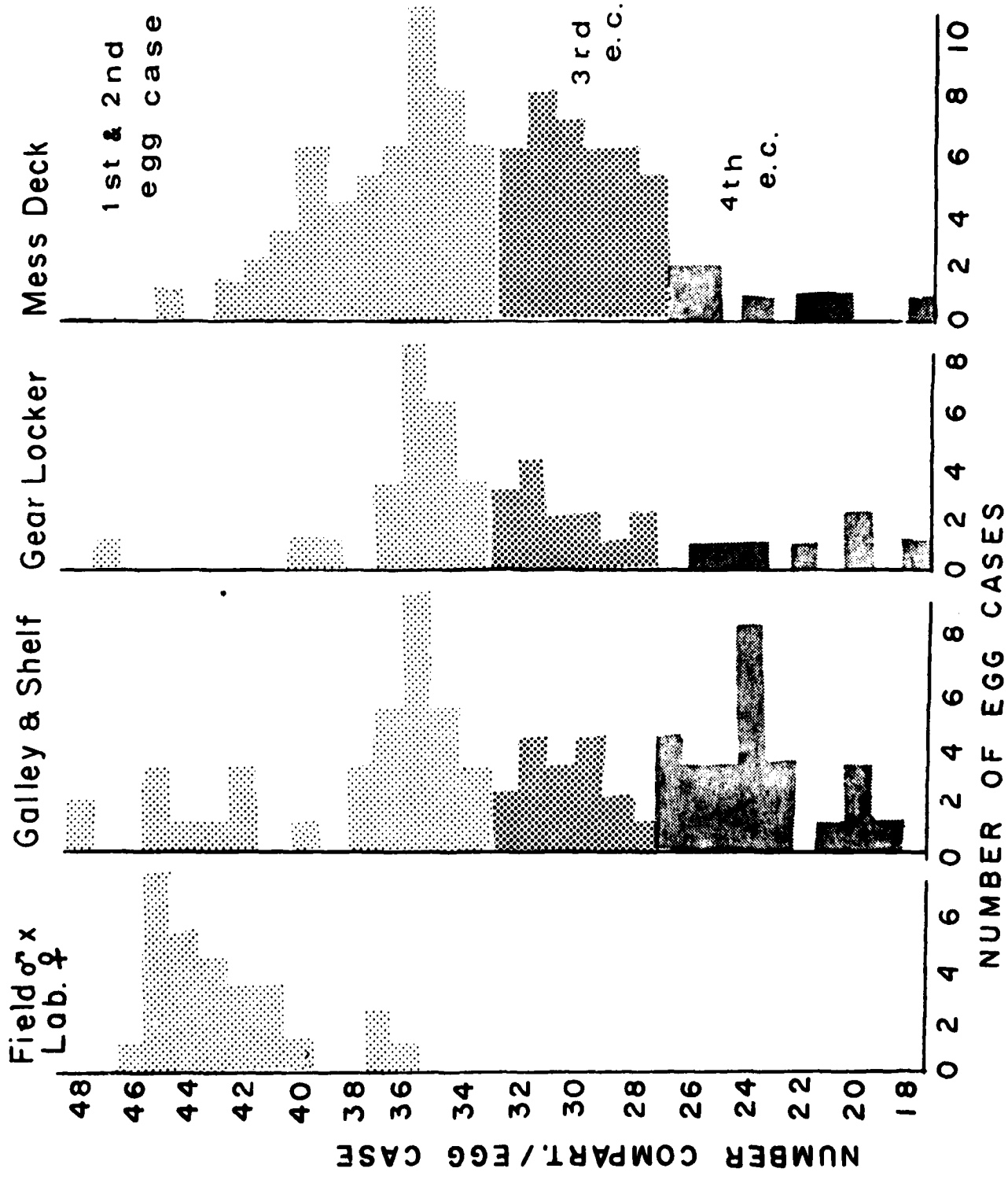
#1-6: release sites; infested at start of experiment.

#7-11: occupied initially & at conclusion of experiment.

#12-17: new sites of infestation.

Figure 2. EGG CASES OF LABORATORY (col. 1) AND FIELD-MATED FEMALES (cols.2-4) GROUPED ACCORDING TO THE APPROXIMATE AGE OF THE FEMALE.

(1st & 2nd egg case - 1 & 2 mo-old females; 3rd e.c. - 3 mo-old females; 4th e.c. - 4 mo-old females).



Results of the analyses of the above types of data will be presented in detail in the manuscript we are preparing for publication. For purposes of this report, we list below some of the major findings and inferences based on this information. This is followed by a summary of the picture of population development/sterility effects that emerges from these observations. Considerations as to the future uses of genetic mechanisms are presented under "5B".

a. New vs initial infestations

	Observation	Inference
1.	Cockroaches present at all initial sites except for the scullery (Figure 1).	Cockroaches at or close to harborage survived treatment and/or returned to initial site. In absence of other cockroaches, sterile males left the scullery. Easy access and sterility levels suggest they entered the bench seat area.
2.	Many new harborages infested in the mess deck area.	Either infested (a) due to insecticide induced dispersal prior to release, (b) by outward flow from population developing at original bench seat site, or (c) by previously established group that was undetected in process of original search & treatment (we consider this unlikely in view of the thoroughness of the latter). Also see #6.
3.	Galley area had heaviest initial infestations; mess deck heaviest at termination of experiment.	Sterile male releases were more effective in controlling growth of galley than of mess deck populations (but <u>not</u> necessarily the case at the original mess deck site). Also see #4.

b. Oothecae categorized as to approximate age and mating type.

4.	Little increase in numbers of egg case-bearing females in galley as compared to mess deck (Figure 2).	Added evidence sterile male releases were more effective in controlling growth of galley populations than those of mess deck as a whole.
5.	More 4th egg case-bearing females (remnants of residual nymphal groups) in galley than mess deck area.	Expected as the galley was the area of heaviest initial infestation (but see #8); small nos. 4th egg cases from mess deck bears out small size of residual nymphal group(s) at time of rel. #1.

6. 84% of the total collection of 4th egg case bearing-females from the galley were collected from the 1st trap; in contrast, 2 traps at the bench seat site only caught 44% of the total collected from the mess deck (bench seat & all new sites).	Nymphs of residual groups (= 4th egg case bearing-females) were in new mess deck harborages prior to release #1, i.e., the sites were infested by dispersal of nymphs from the bench seat. Otherwise the majority would have been trapped at the bench seat.
7. 4th egg case bearing-females were trapped in the gear locker.	Also suggests insecticide induced dispersal of nymphs from the bench seat (easy access bench seat to gear locker).
8. In the galley, the proportion of 4th egg case bearing-females was greater than that of 3rds.	Better kill of adult females than of nymphs in the galley, possibly reflecting escape due to greater mobility of nymphs (assuming 3rd egg case females are progeny of females of residual groups, and hence provide a measure of their comparative frequency). Also see #9.
9. More 3rd egg case females trapped at bench seat than in galley.	Reflects occurrence of an untreated harborage(s) at or close to bench seat (ex.: gear locker) which required little movement of adult females, as contrasted to more confined situation in the galley.
10. Avg. 83% sterility among 4th egg cases (Table 2).	Good sterility obtained following 1st release among groups at or near sites of release.
11. Collection of 35 4th egg cases.	Ca. 70 females of residual nymphal groups matured and mated after rel. #1 (50% of 4 mo-old females in lab die or fail to produce egg cases).
12. An adult sex ratio of 1♂:2.75♀ in pre-release population sample.	If there were as many as 70 adult females (#11), 30 wild-type adult males is probably a conservative estimate of the no. present in mo. following rel. #1 (under low density and absence of spraying, post-release male survival probably increased).
	On above basis, avg. sterile male frequency after rel. #1 is estimated at 80% (114 sterile:

	30 wild type). The avg. sterility of 83% among older females agrees well with hypothesis of equal competitiveness.
13. Lowest sterility in 4th egg cases in galley (76%).	In spite of larger nos. of released males, residual nymphal groups sufficiently outnumbered those at other release sites to give a lower sterile:wild-type male ratio (supporting data see #5).
14. Progressive loss of sterility greatest in galley (compare 1st & 2nd to 4th egg cases, Table 2).	More wild-type matings after rel. #1 in galley than other sites (76% sterility among large no. females) partially responsible for more rapid decrease in sterile:wild-type male ratio. However, the magnitude of the drop (76% to 13%) strongly suggests an additional factor (almost certainly the unauthorized sticky tape that was put out in the galley).
15. Maintenance of highest sterility in the bench seat & neighboring gear locker.	Lack of wild-type growth from rel. #1 (10 of 11 4th egg cases sterile); also, higher sterile male frequency among later egg cases (1st-3rds) due to better survival of released males than in galley (fewer sterile males released in bench seat, even counting possible influx from scullery, than were released in the galley, yet there were more females with sterile egg cases in the bench seat-gear locker).
16. Avg. sterility at bench seat higher than among those egg cases of the general mess deck collection that could be recorded for mating type (1 of 10 sterile).	Sterile males joined groups at the bench seat, but did not move out into other areas of the mess deck. Other evidence of non-dispersal comes from the head. There was free access from the galley yet 0% of 11 egg cases were sterile (9 others unrecorded due to immaturity.

c. Relative proportions and numbers within nymphal age classes (Tables 3 & 4).

17. More large nymphs collected from the mess deck area than the galley (Table 4, 170 vs 104, respectively).	Indicates more wild-type matings among residual nymphal groups in mess deck than galley (lg. nymphs = 2nd egg case progeny of these matings). Wild-type matings must have occurred at sites other

		than the bench seat, providing added evidence of insecticide induced dispersal of nymphs (also see #s 5, 6, 15 & 16).
18.	A difference in the proportion of large vs medium-sized nymphs in the mess deck as compared to the galley (3.1:1 vs 2.1:1, respectively).	Supports above in that mess deck populations as a whole had a greater input than galley populations from wild-type matings from wild-type matings after rel. #1, i.e., initiation of wild-type populations following nymphal dispersal into new parts of the mess deck (Figure 1, sites 14-17).
19.	Relatively large no. of young females (Table 2, 1st & 2nd egg cases) as well as large nymphs collected at bench seat & gear locker (Table 3).	Comparison to sterilities and nos. of wild-type matings as seen in galley indicate it is unlikely these grew from residual groups left in the bench seat. Rather, they are strong evidence of nymphal migration from new sites back towards the bench seat, possibly due to overcrowding at new sites.

d. Frequency of sterile males from traps

20.	Sterility among 16 adult males collected from a bench seat trap was 31% (younger females same trap 47% sterile); that among 14 from the galley shelf was 14% (female sterility 33%).	A 31% sterile male frequency is probably more representative of survival than 14% (no exposure to sticky tape). This estimate places the no. of sterile males among those collected from sites/areas of release at 76 (.31 x 244), a survival of less than 50% of the last release (180 males).

In summary, there were marked differences in age class frequencies, growth, and sterility effects between groups in different general areas (galley vs mess deck) and, in the case of the bench seat vs mess deck as a whole, between that at a particular site and others within the same general area. The question here is one we plan to investigate further, i. e., are groups within separate but closely located harborages single populations or do they form a single, freely intrabreeding population? Our data suggest that adult females at least tend to stay within or close to a particular harborage, with any far-reaching dispersal and/or natural migration from established infestations being largely by nymphs. This also will be studied further.

The results have implications in respect to differential effects of insecticide treatment in the various areas. It appears that within the more confined space of the galley, there was good kill of adult females, but somewhat more escape of nymphs, due possibly to greater mobility. In the

Table 2. The frequency of sterile matings among females that mated within the shipboard populations.

Site of trapping	4th egg cases		3rd egg cases		1st & 2nd egg cases	
	No.	% sterile	No.	% sterile	No.	% sterile
galley (including shelf)	21	76	10	60	30	13
serving line	3	100	10	60	18	28
gear locker	7	100	13	85	20	65
bench seat	4	75	29	72	38	55
Total	35	83	62	71	106	46

Table 3. Summary of live collections from trapping.

Site of trap	Age class[a]	1st trap[b]	2nd trap[c]
galley floor	Ad	122 (51♀)	
	Lg	39 (31♀)	
	Md	12 (7♀)	
	Sm	19	
galley shelf	Ad	33 (19♀)	
	Lg	18 (11♀)	
	Md	9 (4♀)	
	Sm	14	
serving line	Ad		59 (41♀)
	Lg		25 (24♀)
	Md		16
	Sm		6
gear locker	Ad	122 (52♀)	9
	Lg	59 (28♀)	6 (5♀)
	Md	15 (7♀)	4 (2♀)
	Sm	26	2
bench seat	Ad	77 (54♀)	64 (54♀)
	Lg	42 (36♀)	14 (9♀)
	Md	9	6 (3♀)
	Sm	16	41

[a]Age classes designated as follows: Ad = adult; Lg = large nymphs (5th & 6th instar); Md = medium nymphs (3rd & 4th instar); Sm = 1st & 2nd instar.

[b]Trapped during wk prior to Aug. 5. [c]Trapped during wk prior to Aug. 17.

Table 4. Summary of collections from cleanout and totals from cleanout and trapping.

Area of collection	Age class[a]	1st cleanout (8/17)	2nd cleanout (8/29)	Totals[b]
galley	Ad	60 (30♀)	3 (2♀)	279 (133♀)
	Lg	21 (11♀)	1	104 (77♀)
	Md	28 (14♀)	0	65
	Sm	12	0	39
gear locker & passageway[c]	Ad	94 (46♀)	3 (2♀)	228 (100♀)
	Lg	75 (41♀)	4 (1♀)	138 (74♀)
	Md	45 (28♀)	1	65 (37♀)
	Sm	2	0	30
mess deck (including bench site)	Ad	125 (74♀)	37 (19♀)	303 (201♀)
	Lg	101 (56♀)	13 (7♀)	170 (108♀)
	Md	30 (15♀)	10	55
	Sm	7	12	76
head	Ad	59 (29♀)	0	59 (29♀)
	Lg	16 (8♀)	0	16 (8♀)
	Md	11 (6♀)	0	11 (6♀)
	Sm	3	0	3

[a]Age class designated as follows: Ad = adult; Lg = large nymphs (5th & 6th instar); Md = medium nymphs (3rd & 4th instars); Sm = small nymphs (1st & 2nd instars).

[b]Total from both trapping and collections made at time of final cleanouts.

[c]Cockroaches from the gear locker & passageway outside the gear locker (essentially a part of the mess deck, Fig. 1 site 14) were combined, but field notes indicated most were from the passageway.

bench seat, a smaller initial infestation was reduced to a very small group. However, a safe refuge close to the bench seat (the untreated gear locker) probably explains the survival of a larger group of adult females than occurred following treatment of the heavier galley infestations. A relatively low number of nymphs survived, but these included those that dispersed to new areas of the mess deck. We believe the development of high density infestations in the mess deck harborages during the 4½ mo the experiment was in progress attests to the reproductive potential of the wild-type cockroach when growing uncontrolled under highly favorable environmental conditions on shipboard. In the course of our continued studies, we plan to acquire additional data through analyses of hatch, nymphal development times, and survival within shipboard populations.

Sterile males found and joined groups at or close to the sites of release. The gear locker, which lies directly behind the bench seat, was the only non-release site at which females bearing sterile egg cases were found. On the other hand, sterile males released in the scullery either died or moved on in search of an inhabited site. We suspect some may have joined the bench seat-gear locker group. From these collections, 10 of 11 female survivors of those that mated following release #1 were sterile. Presumably a number of non-survivors likewise mated with sterile males. It seems likely the 19 males released into the bench seat were helped out by additions from the 19 released in the scullery. In any case, these and other comparisons leave little doubt the sterile males competed well against wild-type males.

Seemingly contradictory results were obtained in respect to sterility effects within galley infestations as compared to those of the mess deck (bench seat sole release site). Better control occurred in the galley in that (1) there was little increase in the addition of new females to the population(s) throughout the 4½ mo the experiment was in progress and (2) final population density was less than that of the mess deck, even though there were more cockroaches in the galley at the start of the release program. The opposite would be predicted if one judged on the basis of the high sterilities and scarcity of wild-type matings among females collected at the bench seat-gear locker sites. The explanation almost certainly lies in the occurrence of uncontrolled wild-type growth at mess deck sites well removed from the bench seat.

There are other aspects of the data yet to be analyzed, such as sex ratio variations, comparative catch from successive traps, and cleanout collections and relationships between known nos. of wild-type matings and progeny groups stemming from them. Nevertheless, we believe the above information covers the more important aspects of the experimental results.

Objective 5B - Future applications of genetic mechanisms.

The present experiment revealed a dual role for genetic mechanisms in future experiments: (1) as part of an integrated experiment in cockroach control, in which sterile males are used to suppress growth, if not eradicate, small residual populations and/or (2) as biological tools for analyses of the behavior and dynamics of free populations. In the latter case, various genetic markers could be utilized.

This first experiment in the use of a sterile male technique for the German cockroach pointed to several aspects of wild-type behavior and population dynamics that need further exploration. The availability of such information would be useful both from the point-of-view of more effective application of conventional control methods and the development of integrated programs for cockroach control. Increased population density on the experimental ship reflected this situation rather than any defect in the genetic tool itself. As a result of the experiment, we are already aware of some of the adjustments that would be necessary for successful application of the technique, and that these differ according to the ship area involved. Thus, in the mess deck we needed additional sites of release, as compared to needing only a relatively small increase in numbers

released in the galley (estimated ca. 30 more males would have given +90% sterility). Traps should be placed in areas peripheral to the initial sites of infestation (release) to detect the development of any new infestations. Adjustments are also needed in the removal type analysis of population size. This will be discussed in a forthcoming paper by C. B. Keil (ms in preparation).

It is also noteworthy that on release the males quickly disappeared into natural hiding places. Apparently there was no increase in sightings after the first 1-2 days. Complaints came about 6 wks after the last release and were the result of population growth, mostly in peripheral areas, rather than the releases. However, if a model experiment were to be conducted in the future, it would certainly be advisable to establish good public relations and an understanding of the purpose of the experiment.

The ease with which sterile males were introduced into the populations and their tendency to remain at or close to sites of release augers well for the use of genetic markers in studies of dispersal, migrations, hatch, nymphal development and survival under shipboard conditions. The major thrust of our effort during the continuation of this Contract will be in these and related types of study. Nevertheless, the utilization of sterile males in future experiments in genetic control remains a viable option.

Papers and manuscripts prepared or published during last year

Cochran, D. G. A genetic determination of insemination frequency and sperm precedence in the German cockroach. Ent. exp. Appl. 26 (in press). 1979.

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Keil, C. B. Population estimation of Blattella germanica populations through the removal method. Ms. ready for final typing.